Modern Concepts of Cardiovascular Disease

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SURGICAL CONSIDERATIONS OF ACQUIRED DISEASES OF THE AORTA AND MAJOR PERIPHERAL ARTERIES*†

I. Aortic Aneurysms**

During the past decade, truly impressive progress has been made in the development of effective therapy for acquired disease of the aorta and major peripheral arteries, particularly aneurysms and occlusive lesions. Aneurysms of the aorta, for example, have challenged physicians for centuries, and although various methods of treatment were devised and attempted, they were palliative rather than curative, with generally disappointing results. Within the past decade, however, curative therapy has been accomplished by the development of the surgical principle of extirpation of the lesion with restoration of normal function. The successful application of this method of treatment is dependent upon many factors: among the most important are the principles of blood vessel suture and arterial graft replacement. Equally striking has been the progress made in the treatment of arteriosclerotic occlusive disease, the gravity of which has long been recognized. Owing to its predilection for involving and blocking such vital arteries as the aorta and those which supply blood to the brain, heart and kidneys, it is by far the most common cause of death and disability among vascular lesions. As a consequence of intensive research and clinical investigations during the past decade, an important concept of the disease has been evolved, leading to the application of highly effective methods of surgical treatment. This concept is based upon the demonstration that in many forms of this disease the atherosclerotic occlusive lesion is well localized and segmental in nature with relatively normal arteries proximal and distal to the diseased vessel. From this fundamental knowledge, methods of surgical treatment were developed to restore normal circulation by removal of the occlusive lesion or by its replacement with a substitute artery. Sufficient experience has now accumulated with these methods of treatment to establish their efficacy.

The advances and developments in more effective therapeutic procedures for these grave problems have been made by the intensive research endeavors of many investigators throughout the world, but owing to limitation of space in this presentation, proper credit to these sources is not possible. Accordingly, this report is concerned primarily with the current status of the surgical approaches to acquired diseases of the aorta and major peripheral arteries, based upon certain observations derived from a review and analysis of our experience with approximately 2,500 cases.

ANEURYSMS

Aneurysms may be classified in several ways, according to the nature and cause of the lesions. Etiologically, for example, they may be classified into congenital and acquired types. The former are relatively uncommon and usually are associated with other congenital anomalies, such as patent ductus arteriosus and coarctation. The latter, by far the more common, are due to arteriosclerosis, trauma, or infection. Pathologically, they may be divided into two types: the true aneurysm in which one or all of the mural layers of the parent artery enter into the composition of the sac, and the false aneurysm in which the sac is formed by perivascular connec-

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** Part II of this article, concerned with dissecting aneurysms of the aorta, will appear in the November issue.

tive tissue, usually following the development of a pulsating hematoma as a result of disruption of the wall of the artery by trauma or infection. Morphologically, they may be divided into three types: sacciform, fusiform, and dissecting. The sacciform aneurysm, as the name implies, has a pouch-like appearance with a relatively narrow neck, constituting the orifice from the side of the parent artery to which the larger sac is connected. Fusiform aneurysms tend to be more spindle-shaped and to involve the entire circumference of the parent artery. Dissecting aneurysms are of intramural origin and are characterized by hemorrhagic intramural separation of the aortic wall in the region of the media usually communicating with the normal lumen by an intimal tear. Because of the distinctive features of this lesion, separate consideration is given to it below.

Pathogenesis and Pathology

The essential factor in the pathogenesis of aneurysms is damage to the medial elastic coat of the vessel. Only the outer adventitious layer remains to withstand the repeated force of systolic impact. Once this medial disruptive process has occurred, whether it results from trauma, infection, or atherosclerosis, progressive dilatation ensues at the weakened area and pressure is exerted on surrounding tissues. Nature's effort to counteract this pathological process apparently takes two directions: One consists in the development of fibrous tissue, presumably produced by a chronic irritative hyperplasia in the perianeurysmal tissues. The other consists in deposition of laminae of thrombi on the inner surface of the aneurysm in an effort to maintain normal size of the lumen. Both of these processes, along with extrinsic support from adjacent structures, tend to retard progress of the lesion. In most instances, however, these efforts are inadequate to cope with the continuous pounding effect of the systolic force, well exemplified in aneurysms of syphilitic origin in which gradual erosion of adjacent osseous structures may take place. For one thing, fibrous tissue is an unsatisfactory replacement of elastic tissue for this purpose and progressively becomes thinner and weaker in the face of the unrelenting force of the systolic pressure. For another, the normal process of organization does not usually occur in the laminated thrombus within the aneurysmal sac. Instead, ischemic liquefaction necrosis takes place usually in the more peripheral portions of the clot immediately adjacent to the outer fibrous wall. These two factors combine to produce further weakness of the aneurysmal sac resulting in progressive enlargement and leading ultimately to rupture of the aneurysm.

Although the underlying pathogenic factor, that is, destruction of the elastic media, is the same for most aneurysms, there are certain characteristic anatomical and pathological features depending upon the nature, location and cause of the aneurysm. Those of syphilitic origin, for example, tend to involve the thoracic aorta, particularly about the arch, and to be sacciform in character. Less often, the syphilitic process may be more diffuse, with the production of a fusiform aneurysm. Arteriosclerosis may also lead to aneurysmal formation in the thoracic aorta, but these lesions are more likely to produce diffuse dilatations of the aorta rather than sacciform aneurysms and to be located in the descending thoracic aorta. Thus, they tend to be fusiform in character.

Of interest in this connection is the fact that whereas, in the past, aneurysms of the thoracic aorta were considered to be predominantly of syphilitic origin, there are reasons to believe that in recent years this incidence is diminishing with an increasing frequency of arteriosclerosis as the cause of these aneurysms. Aneurysms involving the abdominal aorta are predominantly of arteriosclerotic origin. Characteristically, these aneurysms are fusiform, arise just below the origin of the renal arteries, and usually extend distally to involve the bifurcation. Arteriosclerosis is also the most common underlying etiological factor in aneurysms involving the peripheral arteries, and these are also characteristically fusiform in type. Next in frequency in the causation of these peripheral aneurysms is trauma. They are most commonly located in the popliteal and femoral arteries.

Clinical Manifestations

The signs and symptoms of aneurysms usually result from encroachment upon adjacent structures. Accordingly, these manifestations depend largely upon the type, location, and size of the lesion. In its early stages, an aneurysm of the thoracic aorta may be asymptomatic or associated with only slight discomfort. In some instances, it may attain full development without causing significant subjective symptoms until the acute episode of fatal rupture occurs. In most cases, however, clinical manifestations of obstructing, progressive encroachment upon adjacent structures become apparent. Thus, compression of the vena cava and innominate veins by aneurysm of the ascending aorta and arch produces venous distention and edema of the shoulders, head, and neck. Dyspnea and cough result from compression of the air passages and death by suffocation is not uncommon. Blood-streaked sputum is an ominous sign that rupture of the aneurysm into the trachea and bronchi is imminent. Hoarseness may be produced by traction on, or compression of, the recurrent laryngeal nerve as it passes around a large aneurysm of the aortic arch. Sacciform aneurysms arising

anteriorly from the ascending aorta or transverse arch may progress to produce erosion of the sternum and ribs with the appearance of a pulsatile tumefaction on the anterior thoracic wall. Later, the skin overlying such a mass may become inflamed and may even ulcerate. Aneurysms of the distal portion of the aortic arch and descending thoracic aorta, particularly those of syphilitic origin, may cause erosion of the vertebrae and ribs posteriorly. Under these circumstances, pain may be radicular and excruciating.

Cardiac decompensation is usually associated with diffuse aneurysms of the ascending aorta that produce aortic valvular incompetence. Diagnosis of an aneurysm of the thoracic aorta may be suggested by the clinical manifestations, along with roentgenographic demonstration of a pulsating mediastinal mass. In many instances, however, differentiation from a solid tumor may be difficult because transmitted pulsations from the contracting ventricles may give an appearance of expansion of the lesion, or the presence of a thrombus in the sac may restrict intrinsic pulsation. Aortography provides the best means of diagnosis, since it permits visualization of the aorta and can establish the diagnosis of an aneurysm by the demonstration of contrast medium in the dilated lumen.

Aneurysms of the abdominal aorta may be associated with few or no clinical manifestations in the early stages and can remain silent until the acute episode of rupture takes place. More commonly, however, they are characterized by a pulsating mass in the abdomen, accompanied by varying degrees of discomfort. Later, the patient may experience pain in the upper part of the abdomen or lower portion of the back with extension into the groin or lower extremities. Pain is a particularly important and sometimes ominous sign, for it often represents rapid progressive enlargement of the aneurysm and may signify imminent or even actual rupture of the aneurysm with retroperitoneal extravasation of blood. The most common and important physical finding is the presence of an expansile pulsating mass which usually arises at or above the level of the umbilicus and may extend well below this level into the pelvis. The mass may be movable and nontender, but with rapid enlargement and imminent perforation it tends to become fixed and tender. The diagnosis of an aneurysm of the abdominal aorta is usually not difficult since the presence of an expansile pulsating abdominal tumor may be considered pathognomonic. It can usually be confirmed by roentgenographic studies. Although the diagnosis may be established by lumbar aortography, experience has shown that this is usually unnecessary. In the majority of cases, owing to calcification in its wall, it is possible to demonstrate the presence of an aneurysm in ordinary plain roentgenograms of the abdomen, particularly in the lateral or oblique projection.

Except for the presence of a pulsating mass, aneurysms involving the peripheral arteries, particularly the popliteal and femoral arteries, may be asymptomatic in their early stages. In time, however, and as a result of complications, serious and disabling symptoms may occur. These are most commonly due to thrombosis and rupture of the aneurysm. Thus, one of the most common complaints that occur is the result of thrombosis of the aneurysm with the production of arterial insufficiency in the extremities. This is exemplified by the fact that in our own series of cases, slightly more than half the patients complained of intermittent claudication. Rupture of the aneurysm is another serious complication that had occurred in 17 per cent of our series. In 9 per cent of the cases, thigh amputation had previously been performed in the contralateral extremity for this complication.

This serious prognosis of aneurysmal disease, particularly that involving the aorta, has long been recognized and is well exemplified in a number of studies on the natural course of the disease. Thus, from an analysis of a series of 1,113 patients with aneurysms of the thoracic aorta, Kampmeier* considered that the average expected duration of life after the onset of symptoms was six to eight months, varying somewhat with the level of involvement. This is further confirmed by our own experience in a study of 97 patients with aneurysms of the thoracic aorta in which follow-up observations were made over a five-year period prior to the development of excisional therapy. During this period, 91 patients died, the majority from rupture of the aneurysm. Although the average duration of life in aneurysms of the abdominal aorta is somewhat longer, the prognosis in this disease is also grave. Estes,† for example, in his analysis of 102 patients with this condition, estimated that only 10 per cent of the patients aged 65 years would survive eight years, whereas 65 per cent of normal persons of this age would have a life expectancy of this duration. He also found that within a year after the diagnosis was made, one third of them were dead. One half had died within three years, and more than three fourths had died within five years, usually from rupture. Particularly important is the fact that the degree of symptoms had no relation to prognosis, since the patients who were asymptomatic at the time of diagnosis lived no longer than those who had symptoms. Others have reported a similar or even worse prognosis. Wright,** in his follow-up study of 68 cases, found that only about 4 per cent of the patients had survived five years. Thus, the presence of an aortic aneurysm regardless of type or location is a

* Ann. Int. Med. 12:624, 1938.
† Circulation 2:258, 1950.
** Circulation 13:754, 1956.

serious and constant menace to the patient and demands prompt treatment.

Treatment

The only effective treatment of aneurysm consists in extirpation of the lesion with restoration of normal vascular continuity and function. This may be accomplished by one of several methods, depending upon the type and location of the lesion. In sacciform aneurysms, for example, it may be possible to apply an occluding clamp across the relatively narrow neck of the lesion and in this way to perform tangential excision of the aneurysm with repair by lateral aortorrhaphy. In fusiform aneurysms, the entire segment of aorta involved by the aneurysm must be removed and replaced by a graft. For this reason, temporary arrest of circulation through this vascular segment by the application of occluding clamps immediately above and below the aneurysm is necessary during performance of the procedure. Under these circumstances, and depending upon the level of occlusion, serious consequences may ensue because of the cardiac strain produced and because of the possible ischemic effects upon tissues located distal to the occlusion. These considerations apply particularly to lesions of the aorta above the renal arteries and to the carotid arteries. In general, the higher the level of occlusion and the longer the period of interruption of aortic circulation, the greater is the risk from such disturbances, particularly for aneurysms arising above the level of the renal arteries, since below this level temporary interruption of aortic circulation is well tolerated. To overcome this problem, one of several approaches may be employed, depending upon the nature and location of the lesion. These include hypothermia, temporary shunt, extracorporeal circulation, and performance of the procedure in a manner to minimize the period of circulatory arrest. The excised segment of the aorta may be replaced with an aortic homograft, or preferably a suitable substitute of plastic material such as nylon, teflon, or dacron woven tubes. In recent years, our experience has led us to believe that the flexible knitted seamless dacron tube is the most satisfactory vascular replacement for this purpose. Results with the use of this type of vascular replacement in more than 1,000 cases have been excellent.

An analysis of our experience with these methods of extirpational therapy in well over 1,000 cases of aneurysm of the aorta and major peripheral arteries has been most gratifying and supports the conviction that they provide the most effective form of management for this disease. Particularly important is the fact that there are few contraindications to the application of this method of treatment. So long as the proximal portion of the ascending aorta is uninvolved, excision of the lesion is feasible regardless of its location and extent. Thus, aneurysms involving the entire aortic arch have been successfully treated by this method of excision of the entire lesion, including the major branches such as the innominate, left common carotid, and left subclavian arteries and with subsequent restoration of continuity. Similarly, extensive aneurysms involving the descending thoracic aorta and the upper abdominal segment of the aorta, from which arise the major visceral branches such as the celiac, superior mesenteric, and renal arteries, have been resected with restoration of continuity to all of these major branches. Some patients with separate aneurysms of the thoracic aorta and of the abdominal aorta have also been successfully treated by excisional therapy. The most important contraindications to operation are concerned with serious associated systemic disease such as severe or disabling cardiac, renal, or cerebral disturbances.

The operative mortality varies with the type and location of the lesion and is particularly influenced by certain factors such as advancing age, pre-existing heart disease, and acute rupture of the aneurysm. Aneurysms of the thoracic aorta, for example, are accompanied by a higher operative fatality rate than those of the abdominal aorta (Table I). Owing probably to the fact that patients with aneurysms of arteriosclerotic origin are more likely to be of advanced age and to have associated heart disease, the operative risk is greater in this group than in other types (Table II). The influence of age is shown

Table I

Aneurysms of Aorta and Major Peripheral Arteries — Operative Mortality

Type	Number of Cases	Deaths	
		Number	Per Cent
Thoracic aorta	217	66	30
Abdominal aorta	709	52	7
Peripheral arteries	122	2	2
Total	1,048	120	11

Table II

Fusiform Aneurysms of Descending Thoracic Aorta — Operative Mortality

Etiology	Number of Cases	Deaths	
		Number	Per Cent
Arteriosclerosis	49	13	27
Syphilis	23	5	22
Trauma	13	0	0
Others	10	1	10
Total	95	19	20

Table III

Aneurysms of Abdominal Aorta
Operative Mortality

Age	Number of Cases	Deaths	
		Number	Per Cent
22-55	105	5	5
56-65	328	24	7
66-75	243	20	8
76-85	33	3	9
Total	709	52	7

Table IV

Aneurysms of the Aorta
Operative Mortality

Evidence of Heart Disease	Descending Thoracic Aorta		Abdominal Aorta	
	Cases	Deaths	Cases	Deaths
Present	37	14 (38%)	317	43 (14%)
Absent	58	5 (9%)	392	9 (2%)

by the fact that the operative fatality rate of patients in the eighth decade of life is almost twice that of patients in the fourth and fifth decades (Table III). Similarly, the fatality rate in patients with pre-existing heart disease is more than three times greater than that in patients without heart disease (Table IV).

One of the most important factors contributing to operative deaths is acute rupture of the aneurysm. This is well demonstrated by the fact that the operative mortality in our series of aneurysms of the abdominal aorta was more than seven times greater in the group with rupture than in those with nonperforated aneurysms. The operations under these circumstances were performed as emergency procedures on patients

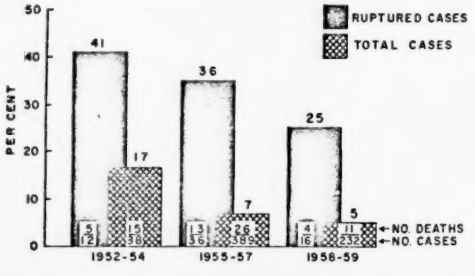

Figure 1. Operative mortality in aneurysm of abdominal aorta.

in shock. The fact that approximate of these patients recovered is high since prior to the development of of therapy, rupture of an aneurysm invariably a fatal complication. R the apparent hopelessness of the s tirpational therapy of a rupture should always be attempted. There believe that improvement in the surg ment of these patients, as well as technical performance of the opera from increasing experience, should ther reduction in the risk, as indic progressive decrease in the opera

Table V

Fusiform Aneurysms of Descendin Aorta—Operative Mortali

Series	Number of Cases	D Numbe
First	33	10
Second	62	9
Total	95	19

rate during the past few years (Tab 1). Finally, studies of long-term resu tion, with follow-up observations ex a period of five years, reveal a si crease in life expectancy (Figure 2).

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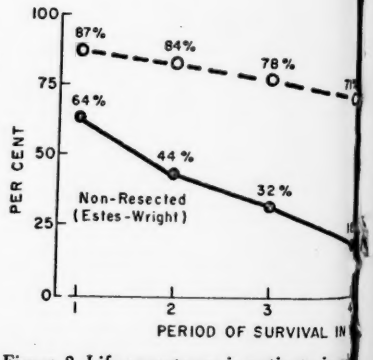

Figure 2. Life expectancy in patients in w of abdominal aorta was resected, as c those in whom the aneurysm was not